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# The Tank Allocation Problem in Bulk Shipping

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## 1 Introduction

Every year 8.7 billion tons of goods or equivalently 80% of world trade by volume is carried by ships (UNCTAD, 2012). This translates into well over a tonne of cargo for every single individual on the planet, every single year, and the global economy therefore depends on the international shipping industry's efficiency and competitive freight rates. Hence, research to increase efficiency within maritime transportation is important, and, taking the mere size of this huge industry into consideration, even small improvements can have great impact.

52% of seaborne trade in dollar terms are containerized (UNCTAD, 2012) and this explains the vast amount of attention given to container shipping by both media and researchers. However, in terms of deadweight tonnage container ships only account for 13% of the world fleet while bulk carriers and oil tankers are responsible for respectively 41% and 33% of world tonnage (UNCTAD, 2012). Therefore, to ensure efficiency of maritime transportation in general there is a need for research within other types of shipping than container shipping and there are in fact great operational differences between the different shipping types creating the need for tailor made models and solution methods for each type. In this paper we consider bulk shipping, both wet and dry, and thereby cover both bulk carriers and oil tankers as well as other smaller shipping segments.

Many bulk ships have multiple tanks and can thereby carry multiple inhomogeneous products at a time. Two examples of such ships are oil product tankers and chemical tankers. A major challenge when operating such ships is how to best allocate cargoes to available tanks while taking tank capacity, safety restrictions for onboard cargoes, ship stability and strength as well as other operational constraints into account. Depending on the number of tanks and the number and type of different products transported at the same time the stowage of cargoes onboard the ship can be more or less complex. A chemical tanker can for instance have as much as 50 different tanks and hazmat (hazardous materials) regulations play a major role when allocating the products to the different tanks. E.g. products in neighboring tanks must be non-reactive and incompatible products must not succeed each other in a tank unless it is cleaned somehow (and this can be costly). These regulations on product succession means that we need to keep track of previous tank allocations and that decisions at any voyage leg affects decisions at future voyage legs complicating the problem even further. Often it is not allowed to move a cargo once it has been allocated to tanks and then this interdependency between voyage legs becomes even stronger. Taking stability,

safety restrictions and other operational constraints into consideration it can therefore be extremely difficult if not impossible to find a feasible allocation for a given set of cargoes. Therefore, there is a need for a systemized approach to stowage of bulk ships that can aid the construction of feasible and good cargo allocations.

The tank allocation problem (TAP) as described above is an operational planning problem but it naturally arises as an important subproblem in tactical planning when determining routes and schedules for a fleet of bulk ships. For each considered route the TAP must be solved to assess route feasibility with respect to stowage. If the routing and scheduling problem is solved in a way that requires assessment of numerous routes, as for instance in dynamic column generation and local search based methods, the solution time for the entire procedure will only be acceptable if the TAP can be solved efficiently. Furthermore, uncertainty plays a big part in maritime optimization where planners face a constantly changing environment with large daily variations in demand and many unforeseen events and so, it is often necessary to replan routes and schedules continuously to accommodate new cargoes and changes to existing plans. In effect, this means that the TAP must be solved repeatedly and that the requirements for computation time are strict. Furthermore, even if the TAP is not solved repeatedly, some problem instances are so difficult to solve that heuristics are the only realistic solution method. In fact, Hvattum et al. (2009) show that the problem is computationally intractable and specifically advocate for development of heuristic methods for determining feasibility of the TAP. All the above motivate the development of a tailor made heuristic method that can efficiently assess feasibility of a given route.

At a first glance the well researched container ship loading problem seem similar to the bulk ship loading problem and they do share similarities such as stability requirements and spatial separation requirements due to dangerous goods. However, there are important operational differences that call for tailor made solution methods for each of these two shipping segments. To mention a few, we note that the stacking of containers calls for efficient cargo handling to minimize container shifting when loading and unloading containers and this is of course not an aspect in bulk shipping. On the other hand, containers in a way act as individual tanks for the cargoes meaning that all constraints relating to individual tanks in bulk shipping can be neglected for container shipping. Examples of such constraints are the individual tank capacities, tank characteristics such as coating as well as tank cleaning and prohibited product succession for incompatible products following each other in a tank. Note that the product succession constraints means that for bulk shipping we need to keep track of past cargo allocations and not just present allocations as in container shipping. Furthermore, when transporting liquid bulk cargo additional capacity constraints are relevant to avoid excessive sloshing in partially empty tanks.

The lack of individual tanks in container shipping means that in many ways the bulk ship loading problem is more similar to vehicle loading problems where the vehicles have smaller compartments. However, in these problems complicating bulk ship operational constraints such as stability and product succession is not considered and so, solution methods aimed at the bulk shipping industry must be developed.

In this paper we explore the tank allocation problem in bulk shipping and devise a heuristic solution method that can find feasible cargo allocations. The method relies on a greedy construction heuristic for finding feasible allocations and local search for improving initially constructed allocations. We test our heuristic method on generated data from Hvattum et al. (2009) and compare our method to their optimal one. We find that our method can solve the majority of problem instances extremely fast though it fails at finding feasible solutions for some instances.

## References

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